

Long-term Acoustic Assessment of Bats at Big Dry Creek Jordan, Montana for 2013-2015

Prepared for:

Bureau of Land Management

Prepared by:

Dan Bachen, Braden Burkholder and Bryce Maxell

Montana Natural Heritage Program

A cooperative program of the Montana State Library and the University of Montana

January 2020



Suggested Citation:

Bachen, D. A., B. O. Burkholder and B. A. Maxell. 2020. Long-term acoustic assessment of bats at Big Dry Creek Jordan, Montana for 2013-2015. Report to Bureau of Land Management. Montana Natural Heritage Program, Helena, Montana. 20 pp.

Acknowledgments

This project was conducted with funding from the Bureau of Land Management and would not have been possible without the support of this agency and its staff. Staff at Wildlife Acoustics assisted with questions regarding the SM2Bat+ ultrasonic detector and SMX-US microphone and Kaleidoscope Pro software. Joe and Nick Szewczak provided SonoBat 4.1 software, feedback on its use, and the 2011 Humboldt State University Bat Lab's echolocation call characteristic summaries for western and eastern U.S. bats that we used to develop the call characteristic summary for Montana bats (Appendices 6 & 7 in Maxell 2015). Bowen Deng provided technical support while processing acoustic data on Montana Tech's high performance computing cluster. At the Montana Natural Heritage Program, Darlene Patzer assisted with grant administration, Scott Blum, Shannon Hilty and Alexis McEwan assisted with hand review of bat calls, and Dave Ratz assisted with downloading of weather station data from the Mesowest application programming interface.

Table of Contents

List of Tables	iii
List of Figures	iv
Background	1
Methods.....	4
Bat Detector Deployment.....	4
Data Management & Call Analyses.....	4
Weather Station Data	5
Solar and Lunar Data.....	5
Results.....	6
General Patterns of Bat Activity.....	7
Timing of Bat Activity	8
Temperature and Bat Activity.....	9
Wind Speed and Bat Activity.....	10
Barometric Pressure and Bat Activity	11
Precipitation and Bat Activity	12
Moonlight & Bat Activity.....	13
Species Activity Patterns.....	14
Discussion.....	16
Listed Species Conservation.....	16
White-nose Syndrome	16
Wind Energy Development.....	17
Management Recommendations	19
Literature Cited	20

List of Tables

Table 1. Bat species observed within 50.0 km of the project site prior to the detector deployment (18 Apr 2013). Counts of surveys detecting each species by survey type are provided.	3
Table 2. Species hand confirmed at the Big Dry Creek Jordan detector, by season. Species only observed previously and newly detected within the local area (50.0 km) are noted.	6
Table 3. The number of months each bat species was confirmed by hand analysis of calls identified by automated software, the number of months reviewed, and the respective successful classification rate; only active season data are shown.	14
Table 4. Management considerations for species detected within 50.0 km of the Big Dry Creek Jordan detector. Species presence is summarized by season and include this and any previous efforts.	18

List of Figures

Figure 1. Placement of the Big Dry Creek Jordan detector.....	1
Figure 2. Photo of the detector deployment site at Big Dry Creek Jordan.....	2
Figure 3. Total monthly bat passes recorded at the Big Dry Creek Jordan acoustic monitoring station. Months marked with an asterisk should be interpreted with caution as those data may not represent valid trend due to data collection for only part of that month, equipment malfunction or other issues.	7
Figure 4. Average nightly activity of bats recorded at the Big Dry Creek Jordan acoustic monitoring station across the active season.	8
Figure 5. Average bat pass temperatures (red line) and average background temperatures (black line) across the year at the Big Dry Creek Jordan detector.	9
Figure 6. A comparison of average temperatures during bat passes (red) and average hourly background temperatures (blue) recorded at the KJDN station, located 12.9 km to the west of the detector. Where the bars showing passes exceed hours, bat activity is higher than expected for this temperature bin.	9
Figure 7. The cumulative sum of wind speeds recorded at the KJDN station during bat passes. The speed at which 95% of all activity occurs at or below is highlighted in red.....	10
Figure 8. A comparison of background windspeeds recorded at the KJDN station (blue) and those recorded during bat passes (red). Where the bars showing passes exceed hours, bat activity is higher than expected for this wind speed bin.	10
Figure 9. Hourly changes in background barometric pressure at the KJDN station (blue) compared to changes in pressure when bat passes were recorded (red) at the Big Dry Creek Jordan detector. Where the bars showing passes exceed hours, bat activity is higher than expected for this pressure change bin.	11
Figure 10. A comparison of hours with and without precipitation for bat passes (red) and all nighttime hours (blue) during the active season as recorded at the KIGM8 station, located 56.0 km to the north- northwest of the detector. Where the bars showing passes exceed hours, bat activity is higher than expected for this precipitation bin.	12
Figure 11. Percent of bat passes (red) and background hours (blue) at various moon illumination categories (0% = no illumination and 100% = full moon) and with the moon above and below the horizon. Where the bars showing passes exceed hours, bat activity is higher than expected for this moon horizon/illumination bin.	13
Figure 12. Bat passes through the deployment period identified to species using SonoBat 4.1. Note that these species identification are only suggestions and should only be used to assess general trends for species for which the classifier works well.	15

Background

We established a long-term, ultrasonic acoustic monitoring site on BLM lands in eastern Montana (Figure 1), following deployment and maintenance protocols in Maxell (2015). The detector was placed adjacent to a small lotic waterbody (Figure 2). The surrounding area was not forested and topographically rugged.

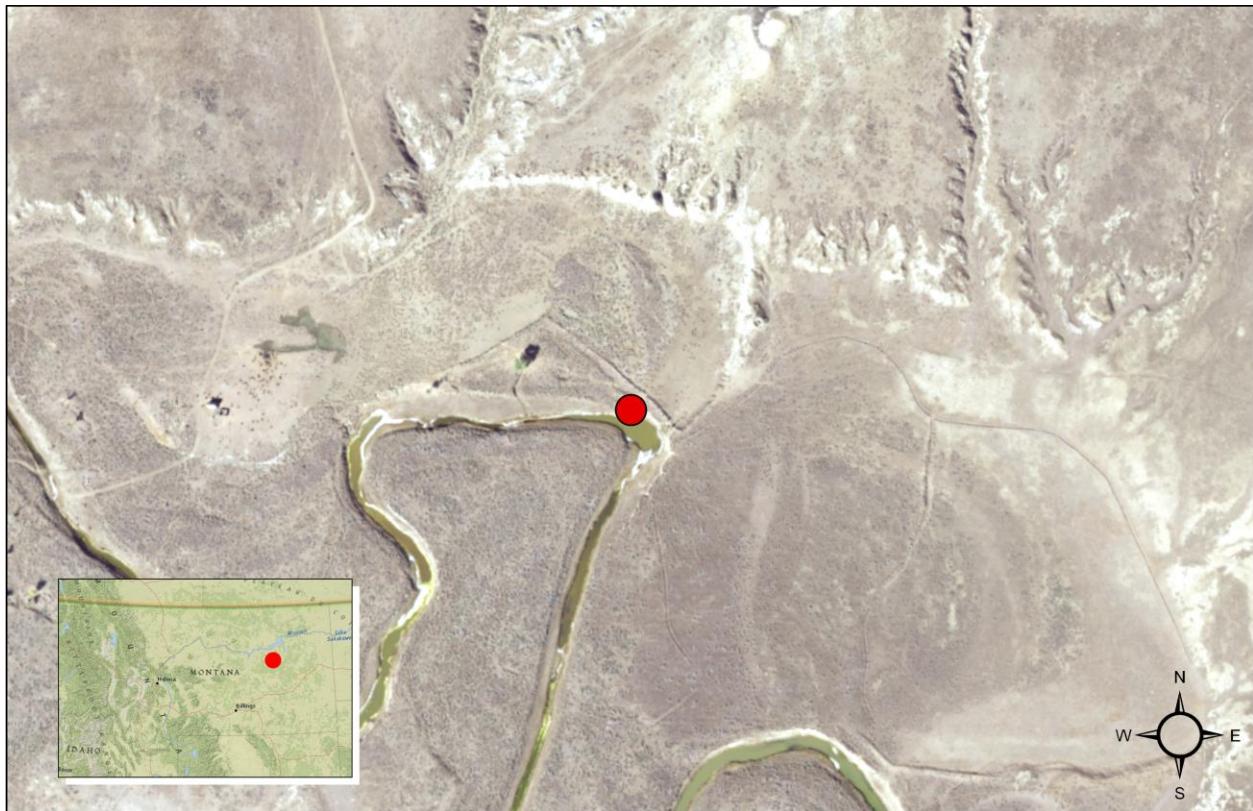


Figure 1. Placement of the Big Dry Creek Jordan detector.

A SM2Bat+ detector with a SMX-US microphone was deployed on 18 Apr 2013 and decommissioned on 13 Mar 2015, for a total of 695 nights deployed. Throughout the recording period the detector functioned well, recording on 694 nights or 99.9% of the time. In total this unit collected data over 24 months and met our minimum of 2 years of deployment for analysis of long-term trends.



Figure 2. Photo of the detector deployment site at Big Dry Creek Jordan.

Table 1. Bat species observed within 50.0 km of the project site prior to the detector deployment (18 Apr 2013). Counts of surveys detecting each species by survey type are provided.

Species	Mist Net Captures	Active Season Roosts	Acoustic Detections	Hibernacula
Big Brown Bat (<i>Eptesicus fuscus</i>)	1	0	5	0
Silver-haired Bat (<i>Lasionycteris noctivagans</i>)	0	0	7	0
Hoary Bat (<i>Lasiurus cinereus</i>)	0	0	7	0
Western Small-footed Myotis (<i>Myotis ciliolabrum</i>)	2	0	3	0
Long-eared Myotis (<i>Myotis evotis</i>)	0	0	3	0
Little Brown Myotis (<i>Myotis lucifugus</i>)	1	0	5	0

Methods

Bat Detector Deployment

Across the acoustic network, detectors were placed at locations to maximize species diversity and bat activity through placement near features important for bats such as roosts, foraging areas, and waterbodies suitable for drinking. We assessed potential sites based on: (1) open water for as much of the year as possible; (2) rock outcrops and trees that might be used as roosts by bats; (3) southern solar exposure that would allow a solar panel to charge a battery even during the winter; (4) year-round accessibility; and (5) a low likelihood of vandalism. At all sites, a detector/recorder unit and microphone were deployed. The microphones at all operational sites in 2015 were upgraded to SMX-U1 microphones (Wildlife Acoustics Inc., Maynard, MA). The detector/recorder was deployed, monitored, and maintained with the equipment, supplies, settings, and protocols listed in Montana's Bat and White-Nose Syndrome Surveillance Plan and Protocols 2012- 2016 (Maxell 2015).

Many aspects of the equipment and site selections influenced the detection of a bat echolocation call and the quality of the resulting recording. These included sensitivity of the individual microphone, temperature, humidity, wind speed, and frequency, amplitude, distance, and directionality of echolocation calls emitted by bats (Parsons and Szewczak 2009, Agranat 2014). The energy of sounds spreading in all directions diminishes by one fourth for every doubling of distance because the surface area of a sphere is related to the square of its radius. Furthermore, higher frequency sounds are diminished over shorter distances because of atmospheric absorption (Parsons and Szewczak 2009, Agranat 2014). Testing of the SMX-US microphone used through June 2015 across the acoustic network indicated that bats emitting frequencies in the range of 20 kHz should be detected at distances of 24 to 33 meters from the microphone while those emitting frequencies in the range of 40 kHz should be detected at distances of 18 to 22 meters (Agranat 2014). These distances are the radii of the relevant spheres of detection around microphones when they are at full sensitivity. However, we know that sensitivity varied over time by an unknown magnitude because some precipitation and freezing events permanently reduced the sensitivity. In 2015 the microphones at active detectors were upgraded to the SMX-U1 microphone, which increased the quality of recorded calls and reduced the effect of adverse weather on microphone sensitivity over time. Due to this change in hardware, comparisons between data collected before and after June 2015 should be made with caution as the different models of microphone may affect the number of calls and species detected. Where applicable, individual reports for each unique equipment configuration were produced to minimize any interpretation errors.

Data Management & Call Analyses

Acoustic file recordings, in both original WAC and processed WAV formats, are stored in the Montana Bat Call Library which is housed on a series of 20-40 terabyte Drobo 5D storage arrays at the Montana State Library as well as a secondary offsite location to protect against catastrophic loss. Acoustic analysis results, temperature files, weather station data, and solar and lunar data were all processed and combined within SQL database tables in accordance with the general workflow pattern for data management and analysis outlined in the text and in Appendices 8-10 of Maxell (2015). Bat call sequences were analyzed with the goal of definitively identifying individual species presence by month and individual species' minimum temperatures of activity in accordance with the Echolocation Call

Characteristics of Montana Bats and Montana Bat Call Identification materials in Appendices 6 and 7 of Montana's Bat and White-Nose Syndrome Surveillance Plan and Protocols 2012- 2016 (Maxell 2015).

Weather Station Data

Weather station data were downloaded using the Mesowest application programming interface (API) as outlined in Appendix 9 of Maxell (2015). Temperature, wind speed, solar, and precipitation data were downloaded from weather stations across the regions. Distance from the detector to the station varied by site and data type. All data from weather stations were averaged by hour and associated with all call sequences recorded within this hour bin for use in our analyses.

Solar and Lunar Data

Solar and lunar data were calculated for all hours of detector deployment using the Python package `ephem` (3.7.6.0), which uses well established numeric routines to produce high precision astronomy computations (see Appendix 10 of Maxell 2015). The underlying code produces results nearly identical to data available from the U.S. Naval Observatory (Astronomical Applications Department). Precise times for sunrise, sunset, moonrise, moonset, and percent illumination at the detector were calculated based on latitude, longitude, and date. It should be noted that local topography is not incorporated into any of these calculations. Therefore, the exact timing of these events on the ground may differ slightly from those produced by this model but should typically be within a few minutes unless local terrain differs greatly from the modeled horizon (e.g. if the site is at the bottom of a canyon).

Results

Species at Site

During the deployment period, 59,389 call sequences were recorded at the Big Dry Creek Jordan detector. Of those, 9,874 (16.6%) were auto-identified to species and 864 were fully reviewed by hand. Of the 101 species-months with calls auto-identified to 10 different species, 32 species-months (31.7%) were confirmed by hand review for 7 species (Table 2).

Table 2. Species hand confirmed at the Big Dry Creek Jordan detector, by season. Species only observed previously and newly detected within the local area (50.0 km) are noted.

Species	Seasonal Presence	Acoustically Detected in Active Season	Acoustically Detected in Winter Season	Observed Previously, not Detected	New Species
Big Brown Bat (<i>Eptesicus fuscus</i>)	Confirmed Year-round	Yes			
Silver-haired Bat (<i>Lasionycteris noctivagans</i>)	Confirmed Year-round	Yes			
Eastern Red Bat (<i>Lasiurus borealis</i>)	Migratory	Yes			Yes
Hoary Bat (<i>Lasiurus cinereus</i>)	Migratory	Yes			
Western Small-footed Myotis (<i>Myotis ciliolabrum</i>)	Confirmed Year-round	Yes			
Long-eared Myotis (<i>Myotis evotis</i>)	Confirmed Year-round	Yes			
Little Brown Myotis (<i>Myotis lucifugus</i>)	Confirmed Year-round	Yes			

General Patterns of Bat Activity

The patterns of activity recorded at the Big Dry Creek Jordan acoustic monitoring station were generally consistent with overall average bat activity patterns recorded across the regional network of acoustic detectors (Figure 3). During the active season, activity increased through the spring onto summer, peaked in July with an average of 7,977 calls recorded, and decreased in the fall. A monthly average of 2,375 calls were recorded between April and October. Activity during the winter was limited, with an average of 3 calls per month between November and March. January had the least activity, with an average of 3 calls recorded.

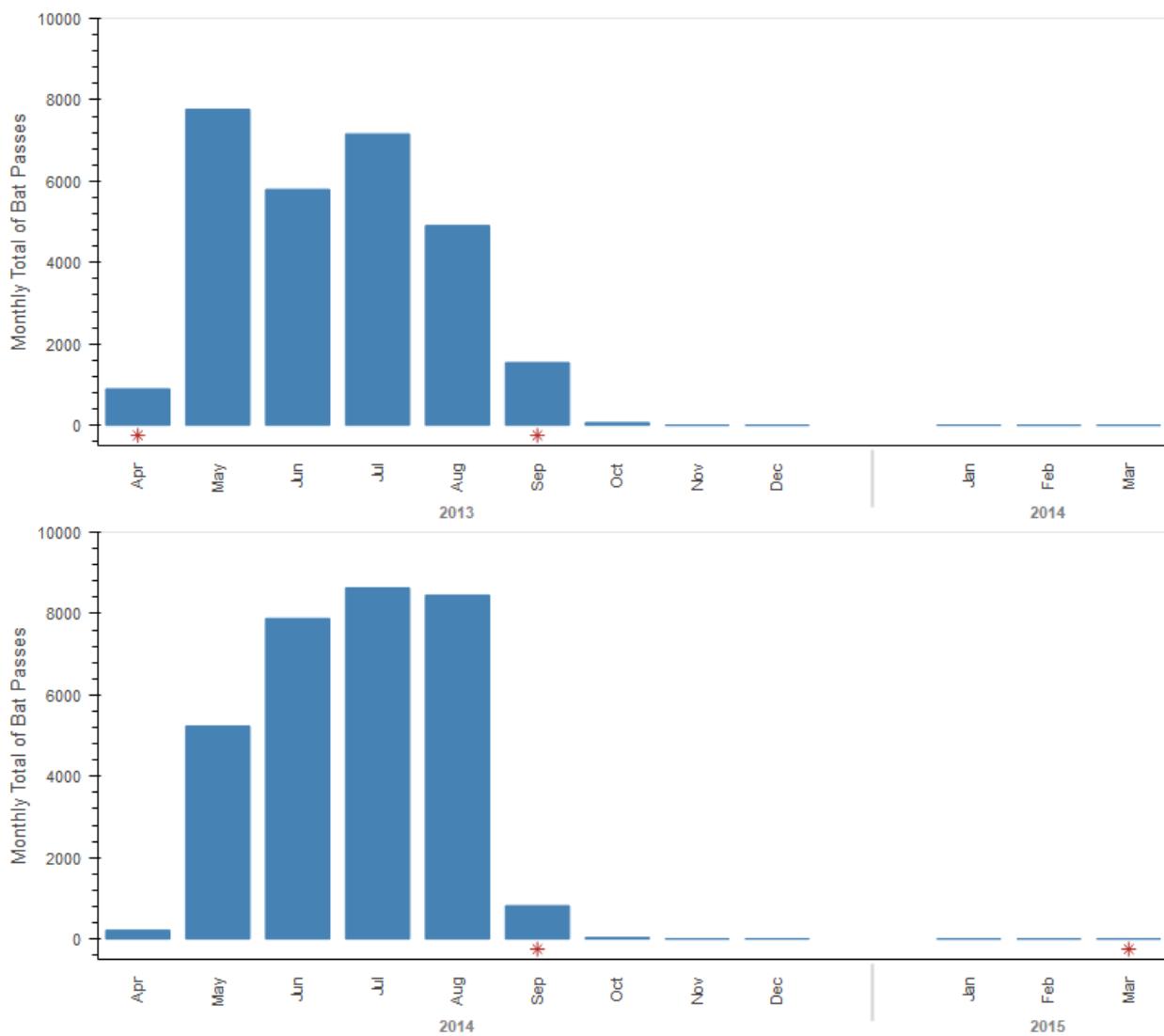


Figure 3. Total monthly bat passes recorded at the Big Dry Creek Jordan acoustic monitoring station. Months marked with an asterisk should be interpreted with caution as those data may not represent valid trend due to data collection for only part of that month, equipment malfunction or other issues.

Timing of Bat Activity

During the active season (April to October), some level of bat activity was evident throughout most of the nighttime hours. Activity often peaked immediately after sunset or close to sunrise. However, the pattern of activity varied across this period (Figure 4), likely in response to seasonal changes in the length of each night, prey availability, and physiological needs of the animals. Over the winter, the pattern of activity was less clearly tied to sunrise and sunset in most cases.

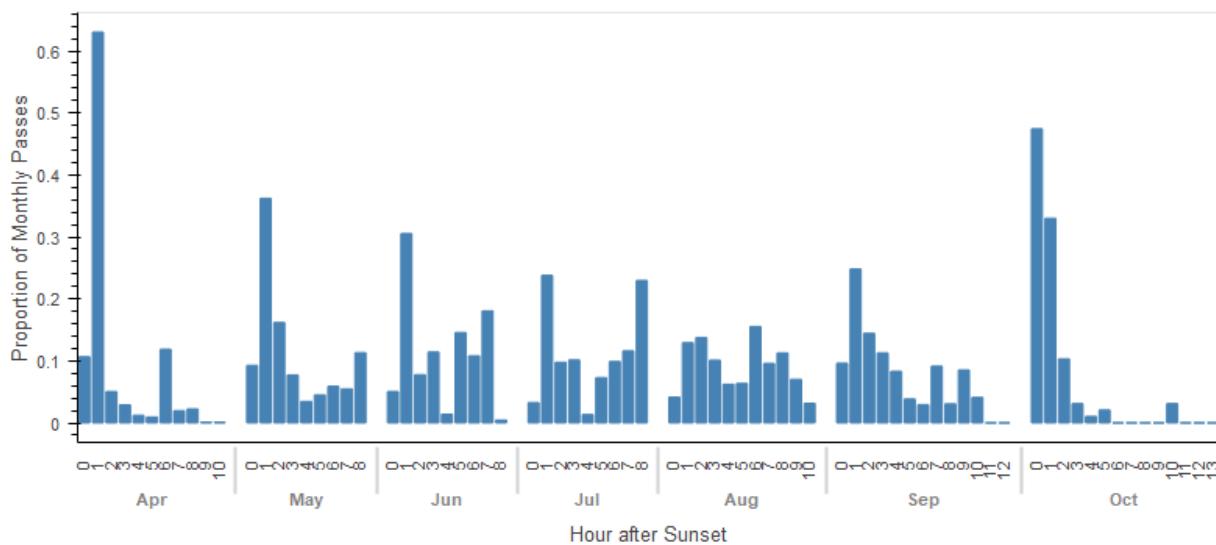


Figure 4. Average nightly activity of bats recorded at the Big Dry Creek Jordan acoustic monitoring station across the active season.

Temperature and Bat Activity

Throughout the study, average bat pass temperatures were generally higher than or equal to ambient nighttime background temperatures recorded at the detector (Figure 5). Bat calls were recorded at temperatures ranging from -4.8 to 30.2°C during the active season and -5.4 to -2.0°C during the winter season. Similarly, the distribution of temperatures recorded at the *KJDN* station, located 12.9 kilometers to the west of the detector, that were associated with bat passes was significantly higher than the distribution of background temperatures (Figure 6). Thus, bats consistently restricted their activity to warmer time periods from the range of background temperatures available.

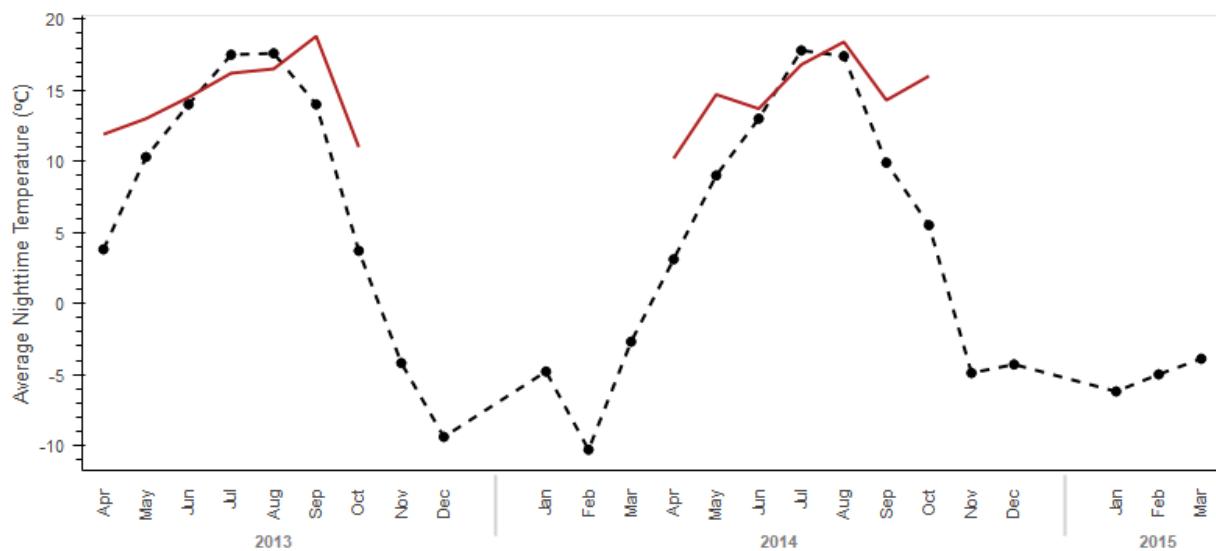


Figure 5. Average bat pass temperatures (red line) and average background temperatures (black line) across the year at the Big Dry Creek Jordan detector.

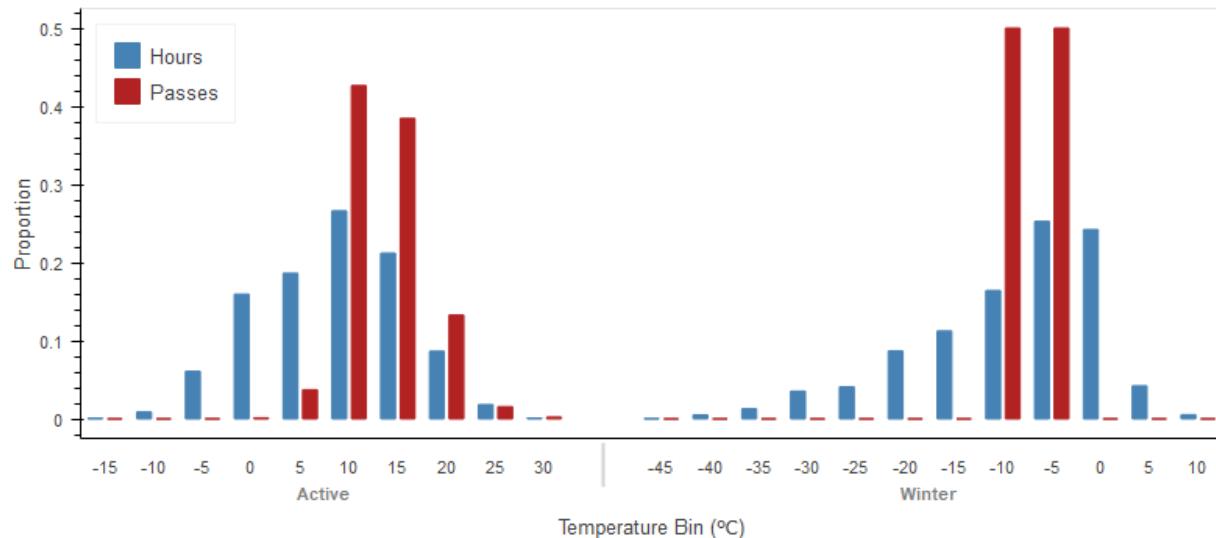


Figure 6. A comparison of average temperatures during bat passes (red) and average hourly background temperatures (blue) recorded at the *KJDN* station, located 12.9 km to the west of the detector. Where the bars showing passes exceed hours, bat activity is higher than expected for this temperature bin.

Wind Speed and Bat Activity

Bat activity patterns in relation to wind speed recorded at the *KJDN* station, located 12.9 km to the west of the detector, indicate that 95% of activity was at windspeeds of 5.7 meters/second and below (Figure 7). Furthermore, bats were more active than expected at windspeeds of less than 5 meters/second (Figure 8). Due to the distance between the detector and the weather station and low bat activity in winter, the patterns shown should be interpreted cautiously (e.g. wind speed at the detector may not correlate with the measured wind speed).

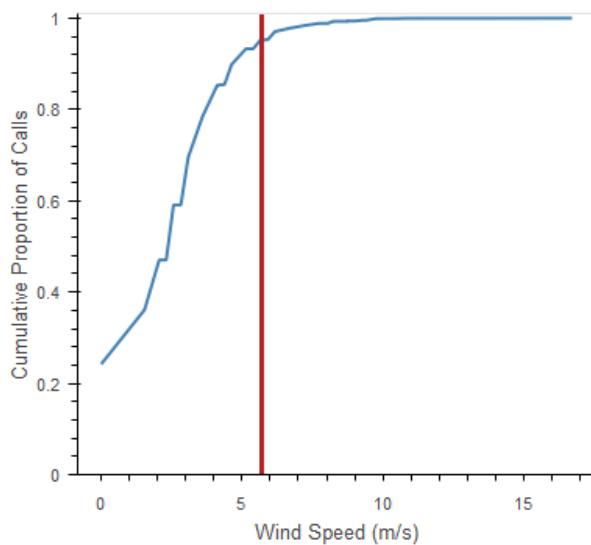


Figure 7. The cumulative sum of wind speeds recorded at the KJDN station during bat passes. The speed at which 95% of all activity occurs at or below is highlighted in red.

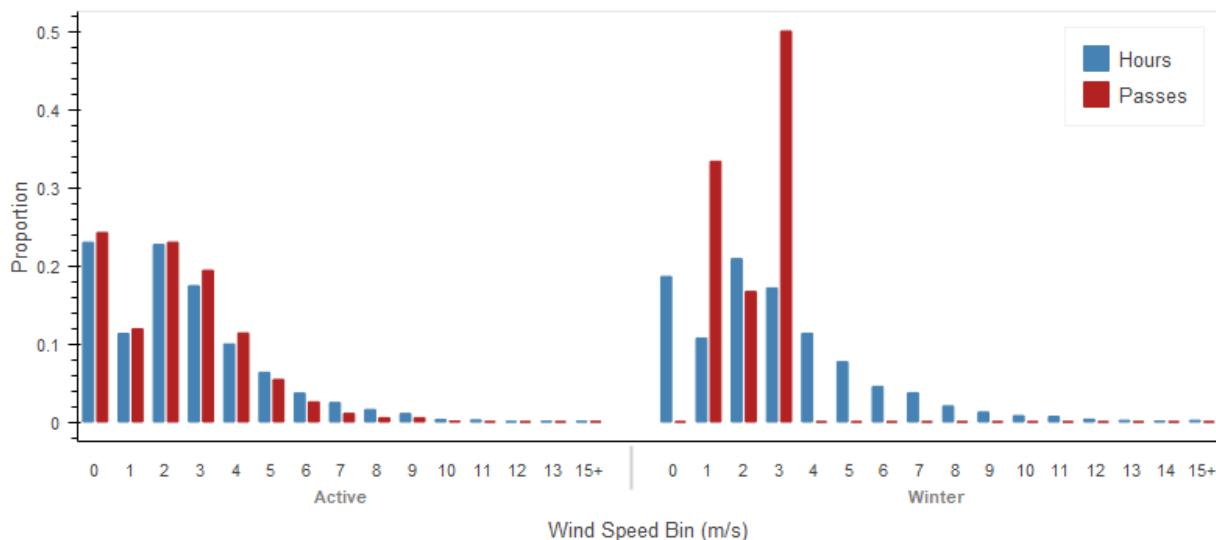


Figure 8. A comparison of background windspeeds recorded at the KJDN station (blue) and those recorded during bat passes (red). Where the bars showing passes exceed hours, bat activity is higher than expected for this wind speed bin.

Barometric Pressure and Bat Activity

Nearly 68.3% of bat activity was associated with little to no change (-0.5 to +0.5 millibars) in hourly barometric pressure recorded at the *KJDN* station, located 12.9 km to the west of the detector (Figure 9). Bat activity was greater than would be expected in the negative pressure change classes down to -4 millibars of change per hour in the active season. During winter, bat activity was greater than would be expected in the negative pressure change classes down to -4 millibars of change per hour. However, bat activity in the winter season is low and patterns shown may not be biologically significant.

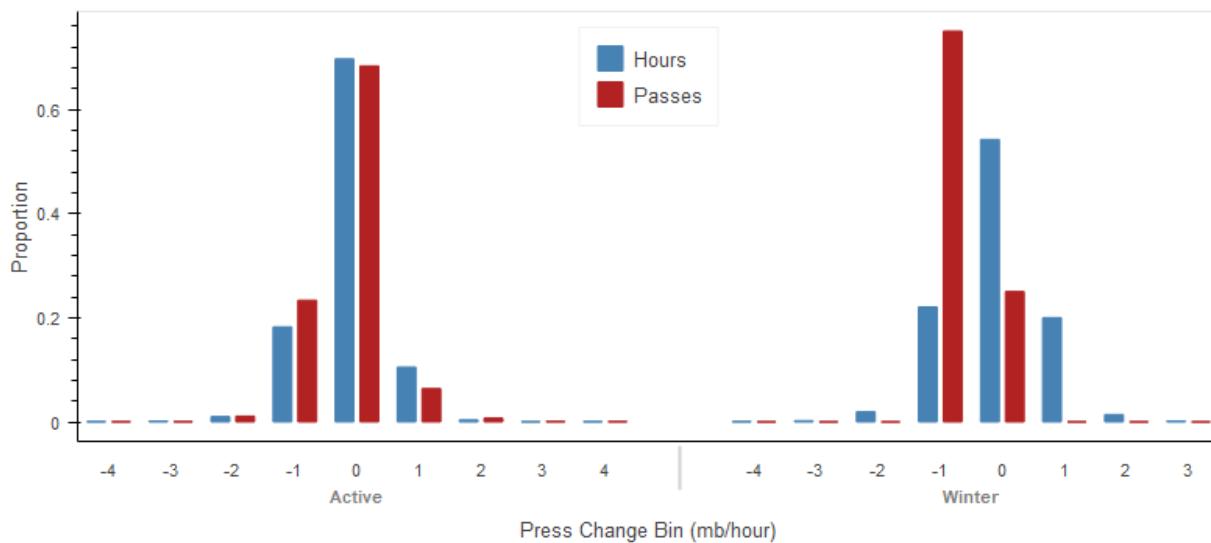


Figure 9. Hourly changes in background barometric pressure at the *KJDN* station (blue) compared to changes in pressure when bat passes were recorded (red) at the Big Dry Creek Jordan detector. Where the bars showing passes exceed hours, bat activity is higher than expected for this pressure change bin.

Precipitation and Bat Activity

At the Big Dry Creek Jordan detector, the distribution of bat activity was approximately equal to the distribution of hourly precipitation with no apparent selection for or against hours with precipitation. This may simply be a result of the facts that: (1) nighttime precipitation events are infrequent with only precipitation documented during only 4.7% of nighttime hours; (2) the *KIGM8* weather station is approximately 56.0 kilometers away and may not accurately represent precipitation at the bat detector, and (3) precipitation was coded in hourly bins while bats are capable of flight within minutes after the passage of a storm front.

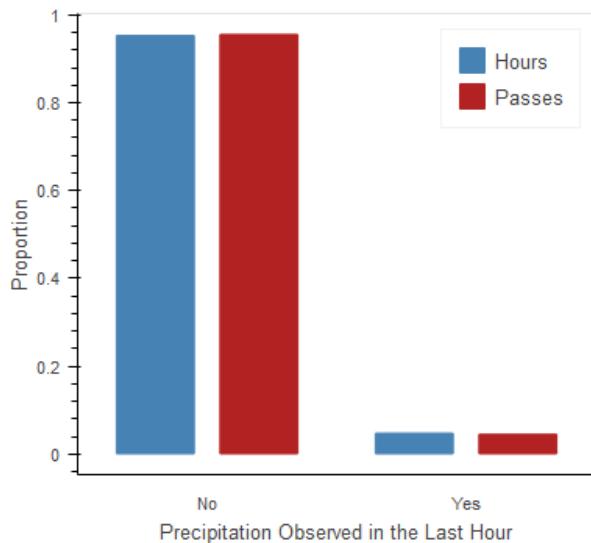


Figure 10. A comparison of hours with and without precipitation for bat passes (red) and all nighttime hours (blue) during the active season as recorded at the KIGM8 station, located 56.0 km to the north-northwest of the detector. Where the bars showing passes exceed hours, bat activity is higher than expected for this precipitation bin.

Moonlight & Bat Activity

At the detector site, bats were generally more active than expected during dark periods where the moon was either below the horizon or less than half full (Figure 11).

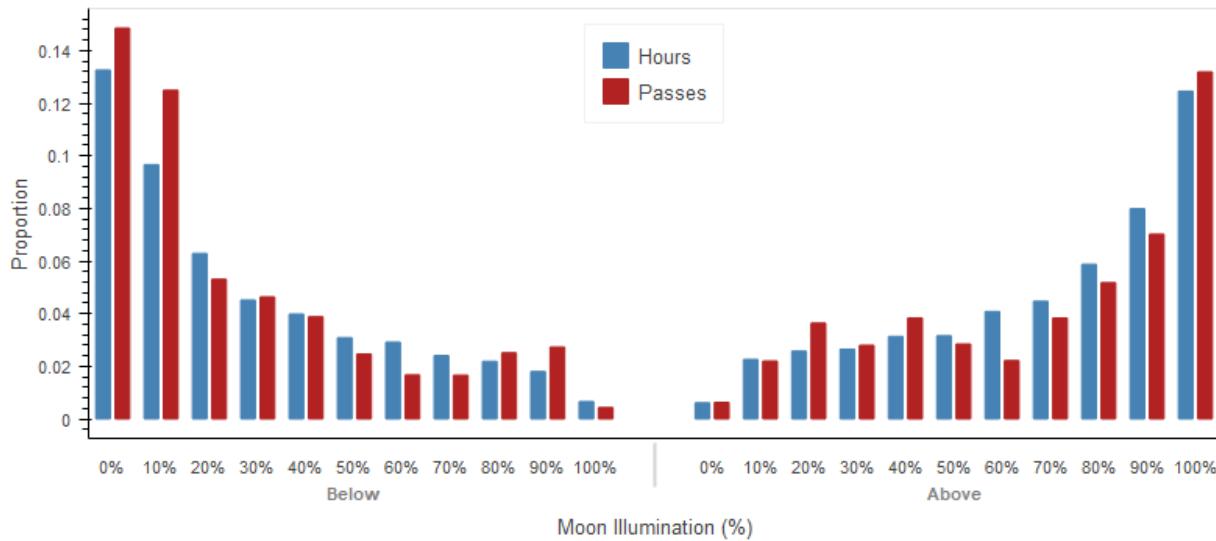


Figure 11. Percent of bat passes (red) and background hours (blue) at various moon illumination categories (0% = no illumination and 100% = full moon) and with the moon above and below the horizon. Where the bars showing passes exceed hours, bat activity is higher than expected for this moon horizon/illumination bin.

Species Activity Patterns

Identification of individual species activity patterns was hindered by relatively low and potentially inconsistent rates of auto-identification of call sequences to species (Table 4 in Maxell 2015). Only Little Brown Myotis, Long-eared Myotis, Western Small-footed Myotis, Silver-haired Bat, Big Brown Bat, and Hoary Bat had relatively high rates of confirmation of monthly presence, enough calls auto-identified to examine trends, and >50 percent correct auto-identification rates of call sequences of known species identity in the Montana Bat Call Library (Table 3). For those 6 species at this site with high auto-identification confirmation, potential patterns of documented activity are shown in Figure 12. However, activity patterns for these species from auto-identified call sequences should still be regarded as speculative due to a variety of issues that might cause auto-identifications to be inaccurate and/or inconsistent (Maxell 2015).

Table 3. The number of months each bat species was confirmed by hand analysis of calls identified by automated software, the number of months reviewed, and the respective successful classification rate; only active season data are shown.

Species	Months Confirmed	Months Reviewed	Auto-Identification Success Rate
Pallid Bat (<i>Antrozous pallidus</i>)	0	2	0.0%
Townsend's Big-eared Bat (<i>Corynorhinus townsendii</i>)	0	2	0.0%
Big Brown Bat (<i>Eptesicus fuscus</i>)	3	10	30.0%
Silver-haired Bat (<i>Lasionycteris noctivagans</i>)	7	7	100.0%
Eastern Red Bat (<i>Lasiurus borealis</i>)	4	12	33.3%
Hoary Bat (<i>Lasiurus cinereus</i>)	1	11	9.1%
Western Small-footed Myotis (<i>Myotis ciliolabrum</i>)	3	14	21.4%
Long-eared Myotis (<i>Myotis evotis</i>)	7	7	100.0%
Little Brown Myotis (<i>Myotis lucifugus</i>)	7	8	87.5%

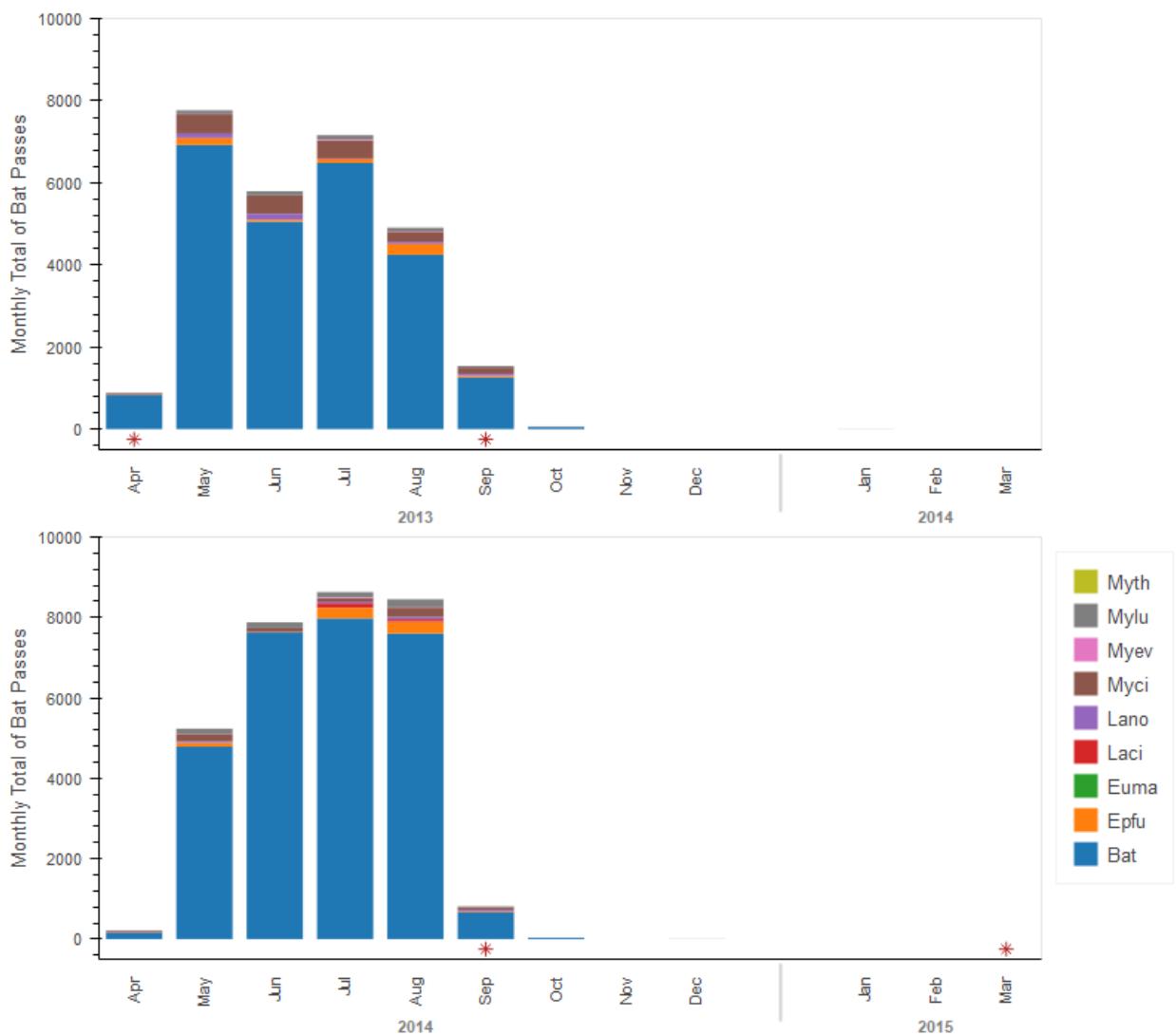


Figure 12. Bat passes through the deployment period identified to species using SonoBat 4.1. Note that these species identification are only suggestions and should only be used to assess general trends for species for which the classifier works well.

Discussion

At this detector we confirmed the presence of 6 of 6 species previously documented in the area (Table 2). Furthermore, we detected 1 species not previously recorded in the area. Of the confirmed species we had 3 species of State Conservation Concern (SOC) and 1 species of Potential Conservation Concern (PSOC). No confirmed species are currently listed as threatened or endangered by the U. S. Fish and Wildlife Service (USFWS). The state and federal conservation or regulatory status for observed species are listed in Table 4.

Species presence and activity metrics recorded at these sites will serve as robust baseline that can be used to assess the status of populations at sites into the future. This is particularly important due to the imminent threats to bat species posed by White-Nose Syndrome (WNS) caused by the pathogenic fungus *Pseudogymnoascus destructans* (*Pd*) and wind energy development. During this deployment, 20 of 24 months recorded met our standards for quality. As such, our assessment is that sufficient data have been collected to document bat activity and species diversity at the site during this time period.

Listed Species Conservation

In Montana, the Northern Myotis (*Myotis septentrionalis*) is the only bat species listed by the USFWS as threatened or endangered. The USFWS has designated 9 counties along Montana's eastern border and North and South Dakota as within the range of this species, and the species has been confirmed as present within three Montana counties (MTNHP 2020). This detector was deployed at a site that was not within the range for this species.

White-nose Syndrome

To-date, the presence of *Pseudogymnoascus destructans* and associated WNS have not been detected in Montana. However, *Pd* and WNS was detected in Washington in 2015 (WDFW, USFWS, and USGS 2016) and in South Dakota and Wyoming in 2018 (NPS 2018, WYGFD 2018). These detections and the continued spread westward into the Great Plains have increased the urgency for establishing baseline metrics to assess future impacts on resident bats. Of the 7 species detected at this site, 3 have been shown to develop WNS when exposed to *Pd*. These species are Big Brown Bat, Long-eared Myotis, and Little Brown Myotis (Table 4). Additionally, Silver-haired Bat, Eastern Red Bat, and Western Small-footed Myotis have been shown to carry *Pd*, but not exhibit symptoms of WNS (Bachen et al. 2018, but see WhitenoiseSyndrome.org for most up to date information on species susceptibility). The remaining *Myotis* species have not been shown to carry *Pd* or develop WNS. Rather than indicating immunity, the lack of detections of *Pd* positive individuals or WNS is likely a result of their western distribution that does not overlap affected areas. As many other *Myotis* species are impacted by WNS, it is probably best to consider these species as susceptible until proven otherwise.

Through the deployment of this and other detectors across the network, we now know that winter activity is normal for many resident bat species and does not necessarily indicate the presence of *Pd* in the local area. At this detector we found that winter activity was in the first quartile (0-25%) of average activity recorded across network sites. As few if any call sequences were recorded over the winter, this lack of bat activity may indicate that few if any animals over winter in the local area." We were unable to confirm the presence of any species during the winter season at this site (Table 2).

Wind Energy Development

Tree roosting species such as the Eastern Red Bat, Hoary Bat, and Silver-haired Bat are not known to be susceptible to WNS but suffer mortality at wind farms. Of these we detected Eastern Red Bat, Hoary Bat, and Silver-haired Bat at the detector site. Due to the presence of these species, mortality due to wind energy is a concern for this area at current and future sites. These species often fly near turbines and suffer barotrauma when near the turbine blades. Due to these species low reproductive rate and long life, unmitigated wind energy development may cause precipitous declines of these species over the next 50 years (Frick et al. 2017). Wind energy may have indirect impacts on bats using this site due to mortality during migration or decreased regional populations. If development of wind energy is considered within the local area, mitigation measures should be implemented to reduce potential impacts on resident and migratory species.

Table 4. Management considerations for species detected within 50.0 km of the Big Dry Creek Jordan detector. Species presence is summarized by season and include this and any previous efforts.

Species	Seasonal Presence	Detected Active Season ¹	Detected Winter Season ²	State Status (Montana)	Federal Status	White-Nose Syndrome Impacts ³	Wind Energy Impacts ⁴
Big Brown Bat (<i>Eptesicus fuscus</i>)	Confirmed Year-round	Yes				Confirmed Susceptible - Mortality Documented	Infrequent Mortality Documented
Silver-haired Bat (<i>Lasionycteris noctivagans</i>)	Confirmed Year-round	Yes		PSOC		Detected - Possibly Susceptible	Frequent Mortality Documented
Eastern Red Bat (<i>Lasiurus borealis</i>)	Migratory	Yes		SOC		Detected - Possibly Susceptible	Frequent Mortality Documented
Hoary Bat (<i>Lasiurus cinereus</i>)	Migratory	Yes		SOC		No impacts	Frequent Mortality Documented
Western Small-footed Myotis (<i>Myotis ciliolabrum</i>)	Confirmed Year-round	Yes				Detected - Likely Susceptible	No Mortality Documented
Long-eared Myotis (<i>Myotis evotis</i>)	Confirmed Year-round	Yes				Confirmed Susceptible - Mortality Documented	No Mortality Documented
Little Brown Myotis (<i>Myotis lucifugus</i>)	Confirmed Year-round	Yes		SOC		Confirmed Susceptible - Mortality Documented	Infrequent Mortality Documented

¹may indicate day roosts and/or maternity colonies present in area

²may indicate hibernaculum or other important winter habitat in area

³see review in Bachen et al. (2018) and WhitenoiseSyndrome.org

⁴see review in Bachen et al. (2018)

Management Recommendations

Measures of overall bat activity near the detector, hand confirmed presence of individual species by month, and hand confirmed minimum temperatures associated with bat passes of individual species are all stable metrics upon which management recommendations can be made. However, patterns of activity of individual species resulting from automated analyses should be used with a great deal of caution due to low rates of species assignment and low or uncertain rates of accuracy of those assignments. Furthermore, it should be noted that bat activity measured during this study was made by a microphone on a nine to ten-foot mast and may not have adequately sampled the activity of high flying bats such as the Hoary Bat and Silver-haired Bat, which together with the Eastern Red Bat are the three species that have suffered approximately 75% of the documented mortalities associated with wind turbines across North America (Kunz et al. 2007). Thus, the following management recommendations avoid use of activity patterns of individual species as determined by automated analyses and instead rely on results of hand confirmed analyses, general patterns of bat activity that were recorded at the study site, and results of published studies of wind turbine impacts on bat species.

General management recommendations for species observed at project sites include:

- (1) Protect potential natural roost sites by conserving large diameter trees (especially snags with loose bark), rock outcrops, cliff crevices, and caves.
- (2) Maintain accessibility for underground mine entrances that bats may be using as summer or winter roosts. Install bat friendly gates if closure is required.
- (3) When removing bat colonies from buildings or other structures follow current best practices, including waiting until the late fall and winter to seal entry points and placing bat houses to compensate for elimination of the roost.
- (4) Reduce structural complexity of vegetation (e.g., short stature grasslands) and availability of standing waters in proximity to wind turbines or other human structures that might represent a threat to bats or where bats are undesired.
- (5) In safe environments, maintain lotic or lentic waterbodies to provide habitat for foraging and drinking.
- (6) If wind turbines are installed in the region, set turbine cut-in speeds to > 6.0 m/sec between April and October – especially important in July during peak bat activity when young are newly flighted, and August, September, and October when migratory species are passing through and local bats are swarming and breeding. Feather wind turbine blades, making them parallel to wind direction, when wind speeds are <6 m/sec to reduce risk of barotrauma during times of relatively high bat activity.
- (7) Report dead bats of any species found in the winter or spring to Montana Fish Wildlife and Parks or Montana Natural Heritage Program personnel. Animals found dead during these seasons may have contracted WNS and should be tested as part of Montana's Passive WNS surveillance protocol.

Literature Cited

- Agranat, I. 2014. Detecting bats with ultrasonic microphones: understanding the effects of microphone variance and placement on detection rates. Unpublished white paper. Wildlife Acoustics, Maynard, MA. 14 pp.
- Armitage, D. W. and H. K. Ober. 2010. A comparison of supervised learning techniques in the classification of bat echolocation calls. *Ecological Informatics* 5(6): 465–473.
- Bachen, D. A., A. L. McEwan, B. O. Burkholder, S. L. Hilty, S. A. Blum, and B. A. Maxell. 2018. Bats of Montana: Identification and Natural History. Report to Montana Department of Environmental Quality. Montana Natural Heritage Program. Helena, MT. 111 pp.
- Clement, M. J., T. J. Rodhouse, P. C. Ormsbee, J. M. Szewczak and J. D. Nichols .2014. Accounting for false-positive acoustic detections of bats using occupancy models. *Journal of Applied Ecology* 51(5): 1460-1467.
- Frick W. F., J. F. Pollock, A. C. Hicks, K. E. Langwig, D. S. Reynolds, G. G. Turner, C. M. Butchkoski, and T. H. Kunz. 2010. An emerging disease causes regional population collapse of a common North American bat species. *Science* 329: 679–682.
- Maxell, B. A. Coordinator. 2015. Montana bat and White-Nose Syndrome surveillance plan and protocols 2012-2016. Montana Natural Heritage Program. Helena, MT. 185 pp.
- Montana Natural Heritage Program. 2020. Animal point observation database. Montana Natural Heritage Program. Helena, MT. Accessed January 2020.
- National Park Service Midwest Regional Office. 2018. Fungus that causes White-Nose Syndrome in bats detected in South Dakota for the first time. News release. May 31, 2018.
- Parsons, S., and J. M. Szewczak. 2009. Detecting, recording, and analyzing the vocalization of bats. Pages 91-111 in Kunz, T. H. and S. Parsons (eds.). *Ecological and behavioral methods for the study of bats* (2nd edition). Johns Hopkins University Press, Baltimore, MD. 901 pp.
- Redgwell, R. D., J. M. Szewczak, G. Jones and S. Parsons. 2009. Classification of echolocation calls from 14 species of bat by support vector machines and ensembles of neural networks. *Algorithm* 2(3): 907-924.
- S. A. Scott, P. C. Ormsbee, and J. M. Zinck. 2008. Field identification of *Myotis yumanensis* and *Myotis lucifugus*: a morphological evaluation. *Western North American Naturalist*, 68(4), 437-443.
- Washington Department of Fish and Wildlife, U.S. Fish and Wildlife Service, and U.S. Geological Survey. 2016. Bat with white-nose syndrome confirmed in Washington state. News release. March 31, 2016.
- Wyoming Game and Fish Department. 2018. Fungus that causes White-Nose Syndrome in bats detected in Wyoming for first time. News release. June 1, 2018.